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GEOPHYSICS.—*Water and the magmatic gases.* ARTHUR L. DAY and E. S. SHEPHERD. Geophysical Laboratory.

Two serious attempts have been made in recent years to establish a conclusion which geologists generally have been somewhat slow to accept, namely, that water of magmatic origin is not found among the gases exhaled by active volcanoes.[1] Notwithstanding the fact that this conclusion is diametrically opposed to the commonly accepted explanations of volcanic activity and the further fact that the evidence offered in both instances is of a somewhat fortuitous kind, it has hitherto remained uncontroverted by well-established facts of observation. It may therefore have some interest to present very briefly the preliminary results of a study of the volcanic gases emanating from the Kilauea crater during the summer of 1912 the ultimate purpose of which is to endeavor to establish the character and effects of the chemical reactions concerned in volcanic activity. It happens that both of the attempts to show that volcanic emanations are anhydrous have depended chiefly upon evidence obtained at this crater.

The character of the evidence hitherto offered may be illustrated briefly as follows. Green noted that active lava flows, and even the Kilauea crater itself, often appear to be giving off gases in quantity when no steam cloud can be seen above them. Brun observed that the cloud when present does not evaporate in the air and shows no optical phenomena in sunlight. He was able to obtain no condensed moisture in glass tubes exposed within

[1] William Lowthian Green, Vestiges of the molten globe, vol. 2. 1887. Albert Brun, Recherches sur l'Exhalaison Volcanique. 1911.

the smoke cloud (100 meters distant from the point of emergence), and he observed further that a dew-point hygrometer exposed within the cloud indicated a smaller moisture content than in the clear air near-by. Some other observations were offered pointing to the same conclusion, but the above citations fairly serve to show the character of the observations which led to the conclusion that water had no part in these exhalations.

It has seemed to the writers, in considering this problem, that evidence of this kind is unconvincing. Such evidence may serve to prove that the cloud above Kilauea does not consist entirely of steam, but it is a very different matter to conclude from it that no steam is emitted, particularly in view of the fact that the extensive hygrometer measurements offered by Brun all show that the observations were made in an unsaturated atmosphere, and the further fact that the temperature of the gases at the moment of emission was not far from 1200°. The latter point seemed to us of vital importance in any attempt to identify volcanic gases, for nearly all the recorded analyses of the gases contained in volcanic rocks[2] include gases (e.g., CO or H_2) which undergo immediate alteration and lose their identity if released into the air at such a temperature as 1200°. We therefore undertook the somewhat hazardous task of going to the bottom of the crater itself and collecting the gases direct from the liquid lava *before they had come in contact with the air* at all.

The gases were collected under the following conditions. A lava fountain broke thru the floor of the crater beside the lava lake and by its own spattering quickly built for itself an enclosing dike. When this dike had grown to a completely enclosing dome, an ideal gas collector was provided by the volcano itself; for this dome, because of the continual bursting of great gas bubbles within, was lined with the same liquid lava from which the gas was being released. From the narrow cracks in the sides of the dome, sheets of pale blue flame could be seen burning at night, which indicated (1) an excess pressure within, and in consequence (2) that the gases released from the liquid lava first came in contact with the air upon emerging from the dome.

[2] R. T. Chamberlin, The gases in rocks, Publications of the Carnegie Institution of Washington, No. 106. 1908.

We accordingly chose a favorable opportunity, descended into the crater and inserted a tube directly into one of these cracks behind the flame which was burning there. This tube was connected with a pipe-line some 7 or 8 meters in length, leading to a train of 20 collecting tubes, each of one-half liter capacity, and finally to a piston pump with a capacity of abour 2½ liters per stroke. The splashing of the lava within the dome could not only be heard and seen thruout the 15 minutes during which the pumping was continued but the jar could be felt beneath the observer's feet. The temperature at which the gases entered the tubes was about 1000°.

With the first stroke of the pump water began condensing in the glass tubes in considerable quantity, in plain view of the observers. This water, tho unexpected (in view of the statement of Brun) also served as a most excellent wash bottle by means of which to trap the halogens or other soluble salts asserted by Brun to be present. At the close of the pumping the tubes were sealed and taken out of the crater without mishap. Four days later the contents of Tube No. 3 were removed for preliminary analysis at the College of Hawaii in Honolulu. With the limited facilities there available, no very elaborate analysis was possible, but the following gases were found:

TABLE I

	Weight Per cent
SO_2	51.6
CO_2	39.8
CO	5.5

It was not possible to analyze for H_2 or N_2, but a 1 : 1 mixture of the gas residue with air gave no explosion on test. The tube also contained about 50 cc. of water with sufficient free sulfur to make it appear quite turbid. This water, when filtered and treated with acid silver nitrate, showed no trace of chlorine. No titanium was found.

The remaining tubes were transported to the Geophysical Laboratory in Washington at the close of the field season (nearly a year later) and analyzed there. The analysis of the fixed gases contained in five of the tubes is tabulated below.

TABLE II

ANALYSES OF THE FIXED GASES (PROPORTIONS BY VOLUME)

	TUBE 1	TUBE 2	TUBE 9	TUBE 11	TUBE 17
CO_2	23.8	58.0	62.3	59.2	73.9
CO	5.6	3.9	3.5	4.6	4.0
H_2	7.2	6.7	7.5	7.0	10.2
N_2	63.3	29.8	13.8	29.2	11.8
SO_2*	none	1.5	12.8	none	none
Rare Gases	none	none	none	none	none
Hydrocarbons	none	none	none	none	none

* Inasmuch as all the tubes contained water, practically all of the SO_2 had gone into solution in the water and become altered before the final analysis was made.

TABLE III

ANALYSES OF THE WATER (PROPORTIONS BY WEIGHT)

	1 grams	2 grams	
Na_2O	0.0214	0.031	The major portion of these may have come from the glass or from Pele's hair.
K_2O	0.0102	0.011	
CaO	0.0120	0.14	
Fe_2O_3, Al_2O_3	0.080	0.010	
Cl	0.220	0.206	
F	0.565	0.492	
NH_3	0.0018	none	
TiO_2	0.005(?)	none	
Total S as SO_3	0.480	0.508	

The conclusions from these analyses may be briefly recounted as follows:

(1) To anyone familiar with gas equilibria, it is immediately obvious that this group of gases can not exist together in equilibrium at a temperature of 1000° or more, but must be in process of active reaction at the time of release from the liquid lava. Reaction will begin between the gases in the rising lava column the moment pressure has diminishd to the point where they begin to be released from solution. As the lava rises to the surface, the pressure upon it diminishes steadily, setting free a continually increasing quantity of gas which is then free to enter into new chemical relations. Moreover, these reactions (e.g., $H_2 + SO_2$ and $H_2 + CO_2$) are of a kind to produce heat in such

quantity as seriously to affect if not to determine the temperature of the whole mass. This chemical activity will be a maximum at the surface at the moment of discharge into the atmosphere and the proportions of the reacting gases will vary with every bubble which bursts from the liquid lava, as is plainly shown by the variations from one tube to another in the above analyses.

It would seem to be a necessary consequence of this mode of release of the gases previously in solution and the resulting exothermic reactions between the gases after release, that the temperature of the lava lake should rise when the quantity of gas given off is large, and should diminish again when the gaseous exhalation diminishes in volume, and this was found to hold true thruout the activity of the summer of 1912 of which we were witnesses. The measured changes in temperature in the lava basin in this interval of about four months (the quantity of lava in the basin remaining practically constant) amounted in maximum to 115° (June 13, 1912, 1070°; July 6, 1912, 1185°).

(2) The exhalation unquestionably contains water, of which about 300 cc. were found condensed in our tubes. In view of the fact that the water condensed and remained behind while the fixed gases passed on thru the tubes and pump, it is not possible from these observations to estimate the proportion of water to the fixed gases.

(3) The presence of free S, SO_2 and SO_3 in the cloud affords adequate explanation of the phenomena observed by Brun. The visible cloud consists mainly of free sulfur (not of chlorides) and we were able to collect it from the cloud, both at the point of emergence and at the crater rim where Brun's observations were made. It follows from this that the cloud would not evaporate in the air nor show optical phenomena (rainbows), neither could it be expected to condense upon the crater walls, nor in tubes, if the point of collection was too far away from the point where the gases were released from the lava. The observations of fact made at Kilauea by Brun are for the most part confirmed by our observations, but we were unable to discover in them any basis for his conclusion that the exhalation is anhydrous, for the tiny sulfur particles would supply abundant nuclei of condensation for any

water in excess of the quantity required to saturate the atmosphere and any quantity smaller than this would evaporate freely in the comparatively dry air at 1300 meters elevation. Furthermore, Brun's observation that the exposure of a dew-point hygrometer within the cloud showed less moisture present than in the clear air outside, finds equally ready explanation in the fact that the cloud has been shown to carry SO_2 and SO_3, and by consequence sulfuric acid, which are excellent dehydrating agents. A cloud charged with drying agents like these must, *a priori*, be found drier than the surrounding air which is not provided with such drying agents. In confirmation of this we find that the decomposition of the surface lava, which is continually exposed to these gases, is everywhere a sulfuric acid decomposition, the decomposition products being sulfates (alum, gypsum) together with considerable quantities of free sulfur.

(4) If the total quantity of gas drawn into our tube system be estimated at about 1000 liters, then the quantity of chlorine is less than 0.02 per cent. In confirmation of this low chlorine content, analyses of the lava near the volcano which has been constantly exposed to the smoke cloud for 20 years or more, showed no test for chlorine in a 2 gram sample.[3]

(5) It is of the highest importance to note further that the nitrogen exhaled by the volcano contains no argon. Bearing in mind that argon is always present in the atmosphere in measurable quantities, and that it enters into no chemical combination whatever, it would seem to be a necessary conclusion that the atmosphere does not contribute to the gases which are given off by the lava. If atmospheric ingredients were present in the lava, then surely the argon must be given off again. This must apply to all atmospheric ingredients including water, whether originally gaseous or condensed, for if meteoric water were to

[3] Brun appears to have tested for chlorine with a silver nitrate solution in an atmosphere which is shown above to contain S, SO_2 and SO_3, and notes that it immediately becomes clouded, but mentions no test to ascertain whether it was the chloride or the sulphite which was thus precipitated. Similarly, he nowhere offers a chemical analysis of the particular gases which he collected in tubes at Kilauea, but contents himself with presenting two analyses of other gases pumped from solid lava fragments reheated *in vacuo* some months afterward. (L'Exhalaison Volcanique, p. 115.)

find its way into the lava it must do so as a gas and on the same terms as the other atmospheric gases, for the reason that the critical temperature of water is but 374°, whereas the lava temperature is 1000° or higher. It is therefore plain that capillary phenomena (Daubrée) can not be invoked to assist in the transmission of water into the liquid lava in the temperature region between 374° and 1000° in which H_2O has no surface tension. But quite apart from this, there is no more reason for assuming that the water is of atmospheric origin than for assuming the carbon compounds to be so.

In conclusion, we may add that the much discussed question whether water is an active participant in volcanic activity appears to find adequate answer in these preliminary experiments, so far as Kilauea is concerned. Not only was water actually collected in considerable quantity (300 cc.) directly from the liquid lava, at a temperature of 1000° or higher, but this was done under conditions which completely excluded contamination with air. Moreover, the presence of free hydrogen associated with CO_2 and SO_2 at this temperature is of itself a sufficient guarantee of the presence of some water among the volcanic gases. Indeed, the reaction between H_2 and CO_2 (the water gas reaction $H_2 + CO_2 \rightleftarrows CO + H_2O$) has long been well known and has been studied in great detail.[1]

BOTANY.—*The botanical name of the lime,* Citrus aurantifolia. WALTER T. SWINGLE, Bureau of Plant Industry.

The lime, altho closely related to the lemon and the citron, differs from them in having small white flowers, fewer stamens, thin-skinned fruits and winged petioles articulated with the blade of the leaf. Because of these and other divergent characters it seems proper to recognize it as a distinct species, as has been done by many botanists. It is quite distinct from *Citrus histrix,* D. C., which is considered by Bonavia[2] to be the ancestral

[1] F. Haber, Thermodynamik technischer Gasreactionen. Berlin, 1905.

[2] Bonavia, E., 1886, On the probable wild source of the whole group of cultivated true limes (*Citrus acida* Roxb., *C. medica,* var. *acida* of Brandis, Hooker, and Alph. de Candolle), in Journal Linn. Soc., Botany, **22**: 213-218, figs. 1-3, (n. 145, Jul. 23).

form from which the cultivated lime was derived and to which Urban[3] refers the lime as a variety.

The earliest postlinnean binomial name applied to the lime was *Limon spinosum*, published by Philip Miller in 1768 in the 8th edition of his Gardener's Dictionary. The specific name spinosum cannot be transferred to Citrus because it would be a homonym of *Citrus spinosus* published by Gmelin in 1774[4] for a form of the lemon quite unlike the lime. The next oldest name, *Limonia acidissima*, was published by Houttuyn[5] in 1774 in spite of the already existing name *Limonia acidissima* used by Linnaeus for the wood apple of Ceylon and India, which name Houttuyn ruled out because he considered it inappropriate, rechristening the wood apple *Limonia pinnatifolia*. Under the rules of botanical nomenclature, no such substitution of names is permitted no matter how inappropriate the original name may be.

The *Limonia acidissima* of Houttuyn was undoubtedly the common lime of the East and West Indies as it was based on the Limonellus sive Limon Nipis of Rumphius[6] and also on an excellent plate published in 1705 by Juffrouw Marie Sibylla Merian,[7] the famous illustrator of insects who spent two years at the beginning of the eighteenth century in Surinam drawing and studying the insects of that colony and the plants upon which they feed.

In 1777 Christmann[8] in the German adaptation of Houttuyn's great work renamed the lime *Limonia aurantifolia*, this name being an avowed substitute for the invalid *Limonia acidissima* of

[3] Urban, I, 1905, Symb. antil., **4**: 321, as *Citrus Hystrix acida*.

[4] Gmelin, S. G., 1774, Reise durch Russland, St. Petersburg, **3**: 278–279.

[5] Houttyun, Martin, 1774, Natuurlyke historie . . . , volgens het samenstel van den Heer Linnaeus, Amsterdam, Deel 2, **2**: 444–445.

[6] Rumphius, G. E., 1741, Herb. amboin., Amsterdam, **2**: 107. tab. 29.

[7] Merian, Maria Sibylla, 1705, Metamorphosis insectorum surinamensium ofte veranderung der surinaamsche insecten, Amsterdam, p. 17, pl. 17 (s. d. but published 1705 vide Hagen, H. A., Bibl. Entom. **1**: 534–535). As Houttuyn does not specify the edition of Merian's work, it may be that he quotes from the second Dutch edition, published in 1719. Color is given to this surmise by the fact that the quotation made by Houttuyn differs by one word from the original text of Juffrouw Merian as published in 1705.

[8] [Christmann, G. F.], 1777, in Linné, 1 'anzensystem nach der vierzehnten lateinischen Ausgabe und nach des holländischen Houttuynischen Werkes übersetzt, Nürnberg, **1**: 618.

Houttuyn. The fact that Houttuyn's name was preoccupied and consequently untenable was doubtless realized by Christmann, altho he makes no mention of his reasons for changing the name. His description and citations of older literature, practically translated from Houttuyn, are ample to establish *Limonia aurantifolia* as a valid species.

The name *Citrus lima* was published by John Lunan in 1814[9] for the common lime and has been recently revived by Percy Wilson (North America Flora, **25**: 222, 1911). This name is a homonym, however, since it was used for the common lemon by Alexander Aitcheson before 1806.[10]

The name *Citrus limetta* Risso, commonly applied to the lime, was published by Risso in 1813[11] but refers distinctly to a variety of sweet lime having an abnormal fruit, probably a garden variety of hybrid origin and certainly not a true lime. This being the type of Risso's species, his name cannot properly be applied to the common acid lime.

The subsequently published names for the lime, such as *Citrus spinosissima* Meyer[12] 1818, *C. acida* Roxburg[13] 1832, *C. Notissimus* Blanco,[14] 1837, *C. Limonellus* Hasskarl[15] 1842, and the many varietal names under the various specific names for the citron, the lemon or *Citrus histrix*, D.C. need not be discussed here as Christmann's name has priority over all of them.

The oldest tenable name for the lime is therefore Christmann's *Limonia aurantifolia* which upon being transferred to Citrus, becomes *Citrus aurantifolia* (Christm.) n. comb.[16]

[9] Lunan, John, 1814, Hortus Jamaicensis, Jamaica, **2**: 451–452.

[10] [Aitchison, Alexander], 18 (?), in Encyclopaedia Perthensis, 2 ed. (?) Perth. **5**: 686. The "New and Complete American Encyclopaedia. . . . From the Encyclopaedia Perthensis with Improvements," New York (John Low), 1806, **2**: 578, gives a verbatim reprint of the description of *Citrus lima* in the edition cited above.

[11] Risso, A., 1813, in Ann. Mus. d'Hist. Nat. Paris, **20**: 195, pl. 2, fig. 1.

[12] Meyer, G. F. W., 1818, Primitae Flora Essequeboensis, Göttingen, p. 247.

[13] Roxburgh, W., 1832, Flora indica, Serampore, **3**: 390.

[14] Hasskarl, J. C., 1842, Flora, **25**, 2 (Beibl.): 43

[15] Blanco, M., 1837, Flora de Filipinas, Manila, p. 607.

[16] The genus Limonia was founded on plants with pinnate leaves. The specific name aurantifolia of Christmann undoubtedly means having orange-like leaves in contrast with the original *Limonia acidissima* of Linnaeus (the *L. pinnatifolia* of Houttuyn and of Christmann).

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this journal and abstracts of official publications should be transmitted thru the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

GEOLOGY—*The Yentna District, Alaska.* S. R. CAPPS. Bulletin U. S. Geological Survey No. 534, pp. 72, with maps, sections, and views. 1913.

The geological formations that outcrop are: (1) a thick slate-graywacke series of undetermined age, but pre-Tertiary; (2) intrusive granites and diorites, probably of Jurassic age; (3) Eocene clays and sands with some lignite; (4) Tertiary gravels; (5) glacial moraines and outwash gravels; (6) recent stream deposits.

The gravel series which overlies the Eocene beds was found to be structurally conformable upon the Eocene, and to antedate by a considerable time interval the period of maximum glaciation. These gravels have hitherto been thought to be Pleistocene.

The placer gold of Cache Creek and the neighboring creeks is thought to have been derived from quartz veins in the slate-graywacke series. Its present distribution has been largely influenced by glacial erosion, the present placers being found only in those places where ice erosion was feeble, or where post glacial erosion has effected a reconcentration of the glacially scattered gold. On Twin Creek and its tributaries the placer gold is the product of post glacial concentration of gold from the Tertiary gravels. S. R. C.

GEOLOGY.—*Bismarck, N. Dak., folio.* A. G. LEONARD. Geologic Atlas of the United States, No. 181. U. S. Geological Survey in coöperation with North Dakota Geological Survey. 1912.

The formations represented range in age from Cretaceous to Recent. The Fox Hills sandstone (marine), the lowest of the formations, is exposed in the lower parts of the bluffs of Missouri River in the southern part of the area and in some tributary valleys. The base is not ex-

posed, but along the Cannonball River, just south of this area, the formation has a thickness of 200 feet. Overlying this over most of the area, in apparent conformity, are 650–700 feet of dark, gray, brown, and black shale and sandstone of the Lance formation (fresh water), the approximate equivalent of the Ceratops beds of Wyoming. In this there is at least one workable 5-foot bed of lignite.

Conformably overlying the Lance or "Somber beds" are the ash-gray and yellow shales and sandstone of the Fort Union (Tertiary), having a maximum thickness of 200 feet. In this are numerous beds of lignite ranging in thickness from a few inches to 35 feet,—thicknesses of 5 to 10 feet are common. In places the lignite has burned out along the outcrop baking the overlying shale to red or pink clinker. The Fort Union carries a rich fossil flora, many freshwater shells and a few vertebrate fossils.

The area, altho outside of the terminal moraines of the Wisconsin stage of glaciation, contains considerable glacial drift. Remnants of moraines, patches of till, and patches of boulders are found, the latter so abundant in places as to form a pavement. This drift, tho indicated on the map as probably of Early Wisconsin age, is in the text provisionally referred to the Kansan stage of glaciation, since the appearance is that of remnants of a much eroded deposit. The western limit of continental glaciation is 50 to 60 miles west of the Missouri in this latitude. Much of the dissection of the area is believed to have been accomplished in Tertiary time but it also appears that there has been a long period of erosion since the deposition of this drift. The valley of Missouri River the author regards as pre-glacial. The economic resources of the area are lignite, clay, gravel, sand, surface and underground waters, and a good soil. WM. C. ALDEN.

GEOLOGY.—*Geologic reconnaissance of a part of the Rampart Quadrangle, Alaska.* H. M. EAKIN. Bulletin U. S. Geological Survey No. 535.

The area treated is in central Alaska, between Yukon and Tanana Rivers west of the 150th meridian. The consolidated stratified rocks of the area include a greenstone group probably of late Paleozoic age, a limestone and schist group of earlier Paleozoic age, a slate, quartzite and schist group, in part of Lower Cretaceous age and a slate sandstone and conglomerate group, probably also of Mesozoic age. These groups trend northeast and southwest across the area in a series of belts, the succession from northwest to southeast being in the order given.

The consolidated stratified rocks are intruded by batholiths and thick sills of monzonite, by a complex system of dikes of widely varying rock types, and by pegmatite and quartz veins. Some pegmatite dikes have centers of pure vein quartz. The solid rocks are overlain locally by loosely cemented Kenai (Eocene) beds, and widely by alluvial deposits. The latter include flood plain deposits of the present streams, stream terrace deposits and high lying silts and gravels. Some of the high lying gravels are evidently beach deposits.

Gold occurs in the metamorphic rocks at a number of places but no workable deposit has been discovered. Placer gold is mined in stream terrace deposits and in the high lying beach gravels. Cassiterite occurs in commercial quantities in some of the gold placers. H. M. E.

ZOOLOGY.—*Description of a collection of unstalked crinoids made by Captain Suenson in Eastern Asia.* AUSTIN HOBART CLARK. Proceedings of the Biological Society of Washington, **26**: 177–182. 1913.

The crinoids listed and described are the following: from near Hong Kong, *Comanthus japonica* (J. Müller), *Zygometra comata* (A. H. Clark), *Catoptometra rubroflava* (A. H. Clark) and *Dichrometra flagellata* (J. Müller); of these only one, *Zygometra comata*, was previously known from this locality; from the Philippine Islands, *Oligometra serripinna* (P. H. Carpenter); from south of the Goto Islands, *Parametra orion* (A. H. Clark); and from northeastern Korea, *Thaumatometra tenuis* (A. H. Clark).

The faunal relationships of the east Asiatic coasts are discussed, and the thirty-six endemic species occurring between southern Japan and Korea and Cochin China are found to fall into four distinct categories: (1) East Indian species, occurring in the Philippine Islands and on the coast of Cochin China, and extending northward as far as Hong Kong, one of them possibly to Fuchow; (2) southern Japanese species, ranging from Tokyo Bay westward to the Korean Straits and thence southward along the Riu Kiu Islands to Formosa (Taiwan) and Hong Kong, where they occur together with East Indian forms; (3) Arctic species, inhabiting the cold water which bathes the continental shores of the Sea of Japan, and ranging southward as far at least as the Korean Straits, possibly even to Shanghai; and (4) Antarctic species, inhabiting the Pacific coast of Japan and reaching their southern limit at Tokyo and Sagami Bays. A systematic list of all the species recorded from the region is given, and the faunal division, to which each belongs, indicated.

A. H. C.

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